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DIRECTORATE OF MATERIALS AND EXPLOSIVES RESEARCH AND DEVELOPMENT

The Use of Non-metallic Materials for Projectile Driving Bands: Part 1: The Development of a Shock-resistant Phenolic Material

W. J. Pullen

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MATERIALS RESEARCH LABORATORY, WALTHAM ABBEY, ESSEX

The Use of Non-metallic Materials for Projectile Driving Bands: Part 1: The Development of a Shock-resistant Phenolic Material

by

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October, 1959.

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DIRECTORATE OF MATERIALS AND EXPLOSIVES RESEARCH AND DEVELOPMENT

The Use of Non-Metallic Materials for Projectile Driving Bands:

Part 1: The Development of a Shock-Resistant Phenolic Material

by

W.J. Pullen

Reference: MR 11/17

Any communications concerning this Report should be addressed to D.M.X.R.D., Ministry of Aviation, Shell Mex House, Strand, London, W.C.2.

1. SUMMARY

This report describes the development of a prototype acrylonitrile/butadiene ("Hycar") modified, nylon cord reinforced, phenolic resin driving band. Bands were moulded from resin-impregnated nylon cord "laid-up" in a pre-form and cured under heat and pressure. The modified resin was produced by incorporating "Hycar" in the phenolic resin by milling, chemical methods of co-condensation being found to be limited in their effectiveness. Firing trials at muzzle velocities of 3000 feet per second showed that all bands were retained in flight. Bands made from a resin containing about 24 per cent of "Hycar" imparted maximum spin and gave reasonable accuracy. Laboratory tests with similar bands showed that they picked up only 3.5 per cent of moisture when immersed in water for 7 months and did not appreciably soften at a temperature of 150-160°C.

2. INTRODUCTION

Experience has shown that copper can no longer be considered a satisfactory material for the driving bands of all projectiles. At muzzle velocities around 3000 feet per second, copper driving bands soften and tend to deposit metal in the gun bore, which results in poor internal and external ballistics. Under the more severe conditions of higher velocities and in automatic fire, copper bands do not give full spin and there is an increase in band pressure, bore expansion and wear due to erosion.

Non-metallic materials have the advantages of being lighter, of giving less barrel wear and possibly improved ballistics and an attempt was therefore made to develop a non-metallic driving band.

Following are the qualitative requirements for a driving band material. It must

(i) impart full spin to the projectile
(ii) obturate and centre the rear end of the projectile in the bore
(iii) be retained in flight
(iv) be reasonably stable dimensionally
(v) function throughout the appropriate Service operating temperature range and in some cases after loading in hot guns
(vi) function in both new and worn guns.

/3. .....

3. SCOPE OF THE INVESTIGATION

This report deals with the development of a nylon cord reinforced, rubber resin modified, phenolic resin material for driving bands. It was assumed that modification of the phenolic resin would overcome its inherent brittleness and that nylon cord reinforcement would improve its shock resistance.

The first phase of the work was to improve the mechanical and physical properties of a phenolic resin by modifying it with butadiene-acrylonitrile ("Hycar") resin, initially by co-condensation but later by mixing on a mill.

The second phase, carried out concurrently with the first, was to improve the meahcnical and physical properties of the resin, by re-inforcing it with fibre, particularly by means of a continuous wound nylon cord. The reinforced material was assessed in the form of moulded-to-size (Fig. 1) driving bands which were subjected to firing trials in a 40 m/L 60 gun. Latterly 120 mm projectile bands were prepared in a pilot plant specially provided.

In this report it is not proposed to deal with all the variants investigated but only the general trends and highlights.

4. THE FABRICATION OF DRIVING BANDS

4.1 Introduction of "Hycar" into Existing Filled Moulding Powders

Initially attempts were made to introduce a butadiene acrylonitrile copolymer containing 40 per cent acrylonitrile ("Hycar 1411") into a standard type woodflour-filled phenolic moulding material by milling. There was no improvement in impact strength however and the resistance to water absorption was not so good. No vulcanising agent was included in the formulation. The inclusion of carbon black (40 per cent calculated on the "Hycar") improved the resistance to water absorption, but the addition of vulcanising agents, for example, equal parts of sulphur and mercaptobenzthiazole, did not significantly improve it.

From these early experiments, however, it appeared that the introduction of "Hycar" improved the flexibility of the resin which is an important factor in ensuring good obturation and engraving. (The results of these experiments are given in Appendix I and II.) It was decided not to continue these adhoc experiments with standard woodflour-filled resins, but to attempt to modify an unfilled phenolic resin with "Hycar".

4.2 Preparation of Unfilled Resins containing "Hycar"

4.2.1 By Co-condensation

A phenol formaldehyde resin catalysed by oxalic acid (J.2010) was used in all the experiments to effect a co-condensation with the "Hycar". Satisfactory condensation was achieved when the oxalic acid content was 1 per cent. The resulting resins were very viscous and when the "Hycar" content was increased beyond 8 per cent calculated on the phenol, the viscosity was too high to permit the resin to be poured from a flask. In an effort to increase the amount of "Hycar" introduced, modifications to the condensation process were made as follows:

(a) Toluene was used as a mutual solvent to keep the "Hycar" in intimate mixture with the phenolic resin. However, the reflux temperature of this system was 85-90°C and the rate of phenol formaldehyde condensation negligible. A similar result was obtained when cyclohexanone was tried as solvent.

/(b) .....

(b) A change was made in the nature of the "Hycar", an acetone soluble "Hycar" (1001) being tried instead. This was first dissolved in acetone and then added to the phenol in a digester. The acetone was distilled off in vacuo leaving the "Hycar" as a solution in the phenol.

The solution was then reacted with formaldehyde in two ways; firstly, using paraformaldehyde and distilling, thereby removing the water formed by condensation reaction, and secondly, by dropwise addition of formalin and again removing the water by distillation.

In each of these experiments the resulting resins were too viscous and the maximum amount of "Hycar" (1001) that could be incorporated was about 10 per cent of the final resin.

4.2.2 By Mill-mixing

From the above experiments it was concluded that co-condensation would limit the amount of "Hycar" that could be introduced into the final moulding. It was decided therefore to try mixing conventional novolac resins and "Hycar" on a compounding mill. Both "Hycar" 1411 and 1001 were investigated and mixes varying from 8 parts "Hycar" and 92 parts resin to 60 parts "Hycar" and 40 parts resin were compounded. Hexamine was used to facilitate cure in the subsequent moulding operation. In order to impregnate the cord filler with the modified resin it was necessary to use a suitable solvent. The most suitable found was one containing 95 parts acetone and 5 parts methanol which permitted complete solution of the "Hycar"/phenol resin mix and of the hexamine. For most of the laboratory tests and firing trials "Hycar" contents of 16, 24 and 35 per cent were used.

4.3 Use of Fibrous Fillers as Reinforcement

4.3.1 Cotton, Asbestos, Rayon and Glass Fibres

Cotton fibres of varying lengths were incorporated into standard novolac phenolic moulding powders and into "Hycar" modified novolac powders. Substantial improvement was obtained in impact strength but resistance to water absorption was impaired. Pretreatment of the cotton fibres with water repellent materials, such as rubber latices and aluminium stearate, did not solve the problem.

Moulded materials containing asbestos fibres had excellent resistance to water absorption but low impact strength. Even lower impact strengths were obtained after milling, owing to reduction in the fibre length.

Some results of these tests are given in Appendix III.

Rayon fibres as fillers gave fair impact strength but had low resistance to water absorption.

By using glass fibres, in particular chopped strand glass, a product with a high impact strength and good moisture resistance was obtained. The material had very poor flow properties however and was extremely difficult to mould into the shapes required. Efforts to overcome these difficulties by pre-heating, plasticising etc. were not successful.

4.3.2 Nylon Cords

The use of nylon cords was investigated at an early stage in the project and the results showed promise in respect of strength and moisture resistance of the

/final .....

final moulding. Tests were carried out on moulding powders with chopped strands, nylon fabric and continuous cord reinforcement. A continuous nylon cord material has a higher impact strength than a chopped cord material but the shear strengths seem to be of the same order. Owing to the limitations of standard test equipment, many impact strengths had to be measured at -40°C and on a smaller size of test specimen than is normally used.

4.3.3 Evaluation of Alternative Nylon Cords

The initial work on continuous cords was carried out on two types of material, a laid nylon cord, i.e. a staple nylon cord of 32 lb breaking strain consisting of three main strands twisted together, and a nylon spindle banding, i.e. a staple cord consisting of six main strands woven to form a sleeving.

Supplies of these two cords came to an end and a comprehensive survey was conducted to discover alternative sources. Five cords which had been submitted as being similar to the original ones were subjected to a full laboratory test programme. From the results a nylon cord defined as a spun nylon netting twine was selected.

4.3.4 Moulding Techniques

In order to produce moulded bands suitable for firing trials using continuous nylon cord reinforcement, suitable techniques had to be developed. An experimental coating apparatus was devised, by means of which the cord was drawn through one or more baths containing a solution of the appropriate "Hycar"/resin mixture. The cord was dried by passing it through a drying tube and then wound on to a spool (Fig. 4).

The treated cord was wound on a mandrel into preforms of shape approximating to that of the finished product, and then moulded in a compression moulding tool under known conditions of temperature and pressure (Figs. 5 and 6).

Details of the composition of the moulded materials and the moulding conditions are given in Appendix IV and V.

5. EXPERIMENTAL PROCEDURE AND RESULTS

5.1 Laboratory Evaluation

The following tests were carried out on the continuous cord materials:

(a) Deformation under load at various temperatures (a measure of the resistance of the material to softening).

(b) Shear strength

(c) Flexural strength

(d) Water absorption at 20°C and 80°C (including dimensional stability).

(e) Impact strength

Test specimens were, in the main, cut from bars processed under the same conditions as the blanks used for firing trials.

The results of the tests are given in Appendices (VI VII VIII IX) and figs. 2 and 3.

/5.2 .....

5.2 Firing Trials

Firing trials were carried out over wet sand using 40 mm projectiles in a QF. 40 mm L.60 gun in the first quarter of its life.

Shots were fired at QE 15° for recovery over wet sand.

Muzzle velocity was obtained by using a 3 channel PCC system and spin by inductive loop and Duddell oscillograph. The results of the trials are given in Appendices X and XI.

6. CONCLUSIONS

6.1 General

Normal phenolic moulding materials are unsatisfactory for use as "stay-on" driving bands. The introduction of butadiene acrylonitrile copolymer into an unfilled phenolic resin and its reinforcement by a continuous wound nylon cord produces a material that shows some promise.

Driving bands made from such a material for 40 mm projectiles are retained in flight and give adequate spin to the projectile. The quality of the engraving is difficult to assess when the projectile has been recovered after firing, but the use of photography in flight may indicate the true quality of the engraving soon after the projectile leaves the muzzle of the gun. The times of flight over a range of some 6500-7000 yards may be sufficient for aerodynamic heating to affect the quality of the engraving.

The effect of the two main variants in this composite material, viz., the percentage of butadiene acrylonitrile ("Hycar") in the resin and the type of nylon cord used are given below:

6.2 The Effect of "Hycar" Content

(a) Increase in the "Hycar" content results in a decrease in the resistance to water absorption at 20°C, and the effect is accentuated at 80°C.

(b) Shear strength decreases with increase in "Hycar" content.

(c) Impact strength, as measured by a notched $\frac{1}{2}$ inch x $\frac{1}{2}$ inch Izod test specimen, seems to be unaffected.

(d) The strength in flexure likewise seems to be unaffected by the "Hycar" content.

(e) The amount of deformation under heat and pressure increases as the "Hycar content is increased.

(f) In firing trials at muzzle velocities of about 3000 feet per second in a 40 mm gun, increasing the "Hycar" content from 8% to 45% makes little difference to the accuracy of the projectile. If the "Hycar" content is too low there is poor bonding between resin and fibre. A reasonable limit is probably 16-24% "Hycar".

6.3 Effect of the Type of Cord

Of the two main types of cord discussed, the laid nylon cord gives better resistance to water absorption, better directional shear strength and greater resistance to deformation under heat and pressure. The impact strength and

/strength .....

strength in flexure are not dependent on the nature of the cord. At a muzzle velocity of about 3000 feet per second there is little to choose between the two types as far as projectile accuracy is concerned, but the overall superiority of a laid nylon cord may become apparent when larger calibre projectiles are fired.

The need to make larger driving bands has meant the development of a small pilot plant to speed up the production of coated cord. Furthermore, probable future Service requirements have led to the investigation of the effect of chopped cord length on the mechanical properties of the final moulding material. As the continuous cord material seems to have adequate strength for retention in flight, it may be possible to use a chopped nylon cord and still retain the band in flight.

7. ACKNOWLEDGEMENTS

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/APPENDIX I .....

APPENDIX I

Introduction of "Hycar" 1411 into Standard Woodflour-filled Phenolic Moulding Powder

Reference	1	2	3	4	5	6	7	8	9	10	11	12	13
	STANDARD GRADE	REPLACEMENT OF WOODFLOUR WITH HYCAR				REPLACEMENT OF RESIN WITH HYCAR				HYCAR ADDED TO CONSTANT RESIN/WOODFLOUR RATIO			
Woodflour (%)	50	47.5	45	42.5	40	50.1	50.2	50.4	50.5	48.8	47.6	46.5	45.5
Resin (%)	42.4	42.4	42.4	42.4	42.4	40.1	37.8	35.5	33.15	41.4	40.4	39.5	38.6
Hycar (%)	NIL	2.5	5.0	7.5	10.0	2.40	4.83	7.26	9.71	2.44	4.76	6.98	9.09
Impact Strength (ft. lb) ($\frac{1}{2}$ in. x $\frac{1}{2}$ in. notched)	0.19	0.19	0.20	0.21	0.23	0.22	0.20	0.20	0.23	0.20	0.20	0.21	0.24
Tensile Strength ($lb/in.^2$)	8270	7420	7740	6780	6540	7520	7590	6220	4920	6990	6760	6910	5400
Water Absorption (mg) 7 days at Room Temp.	161	172	206	209	249	178	211	315	465	161	198	238	307

RESIN:- A phenol novolac (oxalic acid as catalyst) J.2010

TESTS TO BS.771

/APPENDIX II .....

APPENDIX II

The Effect of adding Carbon-black to a "Hycar" modified Phenolic Resin reinforced with Woodflour

Ref.	1	2	3
Resin J.2010 (%)	42.37	42.37	42.37
Woodflour (%)	24.98	19.98	14.98
"Hycar 1001 x 76" (%)	24.98	24.98	24.98
Carbon Black (%)	-	5.00	10.00
Hexamine (%)	5.07	5.07	5.07
Stearine (%)	1.60	1.60	1.66
Magnesia (%)	1.00	1.00	1.00
Impact Strength (ft. lb) ($\frac{1}{2}$ in. x $\frac{1}{2}$ in. specimen)	0.40	0.35	0.33
Cross break strength ($lb/in.^2$)	4310	5360	5980
Water Absorption (mg)	329	213	152

/APPENDIX III .....

APPENDIX III

Comparison of Various Fillers (no "Hycar" in the Resin)

Ref.	Filler	Impact Strength (ft.lb) +	Tensile Strength (lb/in^2)	Water Absorption (mg) x
1	Ground Cotton	0.40	5960	195
2	A	0.35	5370	199
3	B	0.27	6040	180
4	½ in. Cut Cotton	0.86	5140	265
5	A	0.85	5760	250
6	B	0.71	4760	207
7	Diced Cotton	1.20	7600	281
8	A	0.97	6440	255
9	B	0.67	6060	218
10	Ground Nylon	0.25	6400	42
11	A	0.22	7720	70
12	B	0.18	8120	92
13	Asbestos Powder	0.12	5290	29
14	A	0.14	6130	36
15	B	0.14	6770	58
16	Asbestos (Long Fibre)	0.18	4890	30
17	A	0.15	4870	38
18	B	0.20	6820	57
19	Diced Nylon Fabric	0.53	5280	32
20	A	0.50	6540	43
21	B	0.46	5830	74

In compounds "A" 20% of filler is replaced by woodflour.
" " "B" 50% " " " " " "

+ Standard ½ inch x ½ inch notched specimen.

x 7 days at Room Temperature.

Resin used - a normal phenol novolac (oxalic acid as catalyst). (J.2010)

/APPENDIX IV .....

APPENDIX IV

Composition of Materials used in the Shear, Water Absorption, Flexure, Impact and Deformation Tests

1. The Reinforcement

Laid Nylon Cord	A staple nylon cord 680 yd/lb. 32 lb. B/S. A normal laid or twisted cord consisting of 3 main strands.
Nylon Spindle Banding	A staple nylon spindle banding consisting of 6 main strands woven to form a sleeving.

2. The Resins — Milled mixtures of a phenolic resin (J.2010) and "Hycar" 1001 in various proportions.

3. The Composite Materials

Reference	Composition
207	Nylon Spindle Banding - 24/76 Hycar/Resin
208	" " " - 35/65 " "
215	Laid Nylon Cord - 35/65 " "
217	" " " - 16/84 " "
218	" " " - 24/76 " "
219	Nylon Spindle Banding 24/76 " "

/APPENDIX V .....

APPENDIX V

Notes on the moulding of 40 mm Blanks and Shaped Rings

The initial moulding of continuous coated cord has been carried out in a simple mould, which produces a cylindrical blank of 1 in. internal diameter and a $\frac{3}{8}$ in. wall, the length being controlled by the weight of cord used. From these blanks, 40 mm driving bands to the required profile were machined. In order to save material and time a new mould was designed whereby bands could be moulded to the final shape and size. This meant a saving of some 70% in materials.

Procedure

The central mandrel was first dipped in a solution of stearine in acetone and the solvent evaporated, leaving the mandrel coated with a thin coating of the lubricant. A weighed quantity of the resin-coated cord was wound on to this mandrel which was then placed in the heated mould. After some preheating under contact pressure, the full pressure was applied and maintained for the required time.

Details of a typical moulding operation

Material Reference /207

Cord Staple nylon spindle-banding

Resin Hycar 1001 24%
Resin J.2010 76%
(with 12% Hexamine in the resin)

Resin used as a solution in 95/5 vol/vol. acetone/methanol mix to coat the cord.

Cord Data

Resin Content 31-40%

Volatiles 5-7%

Moulding Conditions

Temperature 165-170°C

5 min. preheat in mould

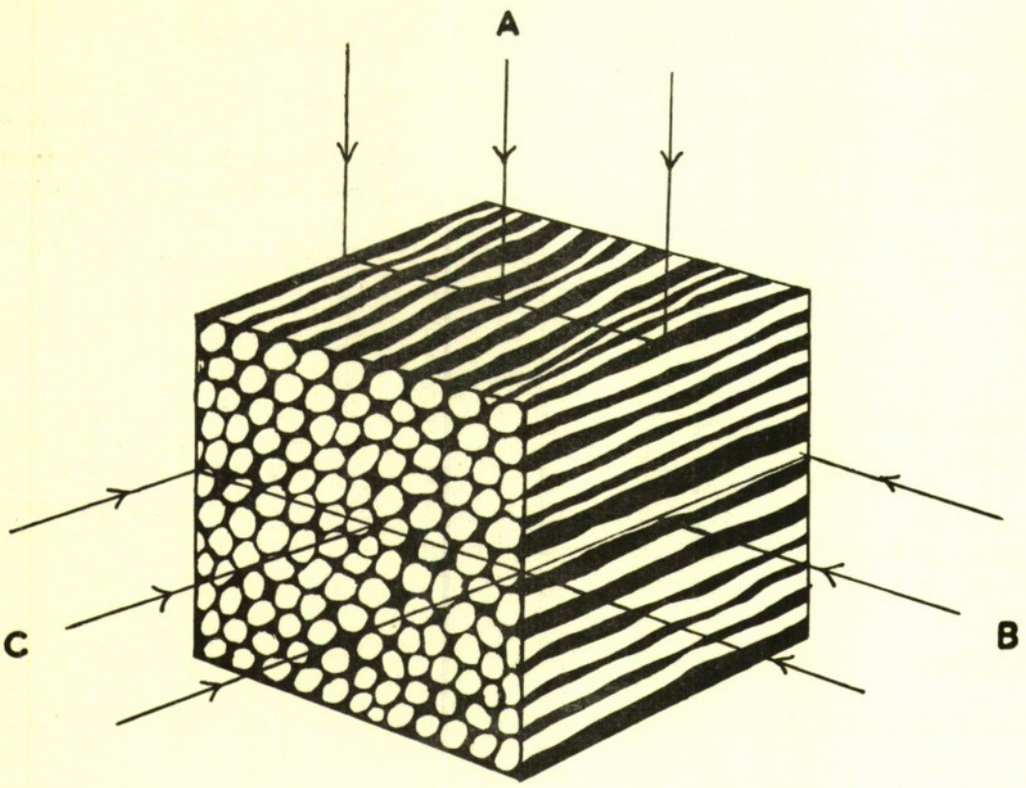
55 min. under 10 tons pressure

Mouldings Resin Content 31-40%

/APPENDIX VI .....

APPENDIX VI

SHEAR STRENGTH (DIRECTIONAL).



MATERIAL REF.	SHEAR STRENGTH lb/inch^2		
	DIRECTION A	DIRECTION B	DIRECTION C
207	6960	4790	3310
208	4870	2970	2100
217	8070	4300	3680
215	8910	4160	5870

APPENDIX VII

Measurement of Physical Properties

(1) Strength in Flexure

Test specimens $\frac{1}{4}$ inch thick by $\frac{1}{2}$ inch wide were supported over a 3 inch span and centrally loaded to failure; the deflection at failure was noted.

Material Ref.	207	208	217	215
Maximum Stress (lb/in.^{2})	2510	2760	6450	5810
Deflection at Maximum Stress (in.)	0.83	0.80	0.86	0.78

(2) Impact Strength

Izod specimens $\frac{1}{2}$ inch wide x $\frac{1}{4}$ inch thick (notched) i.e. notch length is $\frac{1}{2}$ inch

Material Ref.	207	208	217	215
Approx. Impact Strength (ft.lb)	9.5	8.1	10	10

Difficult to measure - specimen often bends instead of fracturing.

(3) Deformation under Heat and Pressure

Method

Specimens $\frac{1}{2}$ inch x $\frac{1}{2}$ inch x $\frac{1}{8}$ inch were placed in an oven for 24 hours under a plunger of $\frac{1}{8}$ inch diameter supporting a 1 Kg load. They were removed from the oven after 24 hours and allowed to cool under load for 1 hour before the deformation was measured.

Reference	Deformation (in.) at			
	100°C	140°C	180°C	200°C
207	0.002	0.006	0.013	0.017
208	0.005	0.008	-	0.029
215	0.003	0.003	0.006	0.006

NOTE This modified Vicat test is not a particularly good one, and it is intended to make measurements on specimens from moulded driving bands.

/APPENDIX VIII .....

APPENDIX VIII

The Effect of Cord Length on the Impact Strength and Shear Strength of the Final Moulding Material

Cord No. 34 Nylon netting twine, diameter 1.45 mm., breaking strain 48.3 lb.

Resin 24/76 Hycar 1001/Resin J.2010

Resin Content of final moulding material 38 - 40%

Material Ref.	Cord Length (in.)	Shear Strength ($lb/in.^2$) Direction (see App. VI)			Impact Strength (Notched Izod) at -40°C (ft.lb/in.)
		A	B	C	
272	½	10,663	5,300	4,090	10.2
273	1	10,886	5,706	4,540	21.4
274	2	10,936	3,773	4,560	29.4
266	Continuous Cord	7,830	3,160	2,875	41.4

APPENDIX IX

Water Absorption Tests

Long-term and short-term water absorption tests were carried out on six different materials; the details of their composition are given in Appendix IV.

Long Term Tests - Total Immersion at Room Temperature

The materials used were Nos. 218 and 219. The specimens were 40 mm. driving bands moulded to the shape and dimensions given in Fig. 1. Changes in weight, external diameter and overall length were measured; the results are given graphically in Figs. 2 and 3.

Short Term Tests - Total Immersion at 20°C and 80°C

The materials used were Nos. 207, 208, 215, 217. The specimens were ½ inch cubes cut from bars moulded under the same conditions as moulded-to-shape driving bands. Changes in weight only were measured and the results are given in the following tables.

/Results .....

Results of Water Absorption Tests
(% Absorption with Time)

N.B. See Appendix IV for details of materials.

1. Effect of Type of Cord (35% "Hycar")

Material Ref.	Days			
	1	3	9	12
at 20°C				
208	0.41	0.56	0.86	0.98
215	0.23	0.38	0.62	0.76
at 80°C				
208	1.40	2.27	3.45	4.07
215	1.28	2.11	3.17	3.67

2. Effect of "Hycar" Content (Spindle Banding)

at 20°C				
208	0.41	0.56	0.86	0.98
207	0.22	0.34	0.55	0.66
at 80°C				
208	1.40	2.27	3.45	4.07
207	1.12	1.79	2.64	3.07

3. Effect of "Hycar" Content (Laid Nylon Cord)

at 20°C				
215	0.23	0.38	0.62	0.76
217	0.17	0.27	0.45	0.54
at 80°C				
215	1.28	2.11	3.17	3.67
217	0.82	1.13	1.54	1.75

/APPENDIX X ....

APPENDIX X

Results of 40 mm/L.60 Firing Trials

Material Ref.	Mean Muzzle Velocity (ft/s.)	Mean Range (Yd.)	Spread of Range (Yd.)	Mean Deflection (Right) (Yd.)	Spread of Deflection (Right) (Yd.)	Spin (%)	Retention (%)
207	3040	6720	238	48	33	NR*	100
208	3054	6700	217	40	28	NR*	100
218	2875	6945	173	135	9	97.9	100
219	2875	6926	156	138	7	98.9	100
215	2881	6984	75	142	7	97.8	100

*NR = No record - Spin Equipment not functioning.

APPENDIX XI

The Results of two Firing Trials to find:-

(a) The effect of the method and degree of impregnation of the nylon cord on band functioning.

(b) The effect of Hycar content in the final moulding material on band functioning.

For these firing trials a new nylon cord was used, a replacement for the existing laid nylon cord.

The new cord was defined as No. 34 nylon netting twine, a fairly hairy cord with diameter 1.45 mm. and a breaking strain of 48.3 lb.

(1) Results of the First Firing Trial

Effect of method and degree of impregnation of the cord

Material Reference /262 - 24/76 Hycar 1001/Resin J.2010 - resin content built up by repeated coatings with a 10% solution (Method 1).

" " /263 - 24/76 Hycar 1001/Resin J.2010 - initial single coating with 25% solution, built up to desired resin content with a 15% solution (Method 2).

/Material .....

Material Reference /264 - 24/76 Hycar 1001/Resin J.2010 - normal double coating using a 15% solution in the first bath and a 25% solution in the second bath. (Method 3).

Impact Strength (Notched Izod) at -40°C

Material Reference /262 43.1 ft.lb/in.
" " /263 40.4 " "
" " /264 47.1 " "

Results of 40 mm/L.60 Firing Trials

Material Ref.	Mean Muzzle Velocity (ft/s.)	Mean Range (Yd.)	Spread of Range (Yd.)	Mean Deflection (Right) (Yd.)	Spread of Deflection (Right) (Yd.)	Spin %	Retention %
262	2816	6083	410	219	98	92.0	100
263	2819	6156	372	195	229	90.0	100
264	2820	6254	140	225	10	90.6	100
Vulcanised Fibre ※	2848	6176	348	133	161	91.0	100

※ Interspersed Controls (Average Results)

(2) The Results of the Second Firing Trial

The Effect of the Hycar Content of the resin

Cord impregnated by Method 2.

Material Reference /265 - 8/92 Hycar 1001/Resin J.2010
" " /266 - 24/76 " " " "
" " /267 - 45/55 " " " "

Impact Strength (Notched Izod) at -40°C

Material Reference /265 49.1 ft.lb/in.
" " /266 41.4 " "
" " /267 45.4 " "

/Shear .....

Shear Strength (Directional) - (See Appendix VI)

Material Ref.	Shear Strength - (lb/in.^{2})		
	Direction		
	A	B	C
265	12,880	7,670	6,750
266	7,830	3,160	2,875
267	7,480	4,050	2,580

Results of 40 mm/L.60 Firing Trials

Material Ref.	Mean Muzzle Velocity (ft/s.)	Mean Range (Yd.)	Spread of Range (Yd.)	Mean Deflection (Right) (Yd.)	Spread of Deflection (Right) (Yd.)	Spin %	Retention %
265	2,810	6,268	126	83	17	89.6	100
266	2,832	6,361	338	82	19	89.3	100
267	2,835	6,432	187	85	14	89.6	100
Vulcanised Fibre	2,848	6,176	348	133	161	91	100

Resin Content (approx.) in both experiments = 38 to 40%.

M. No. 567/59
S. No. 665/BIC

FIG. 1. MOULDED TO SIZE 40MM. DRIVING BAND.

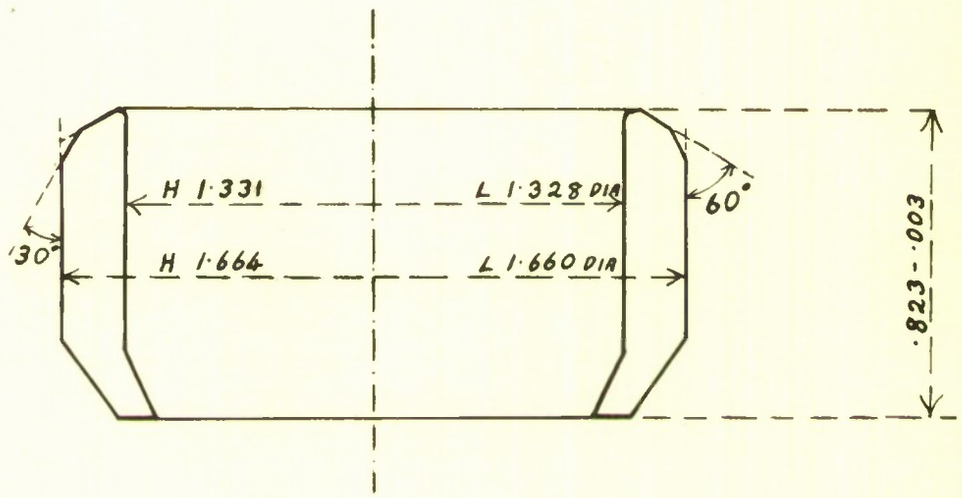


FIG. 2.

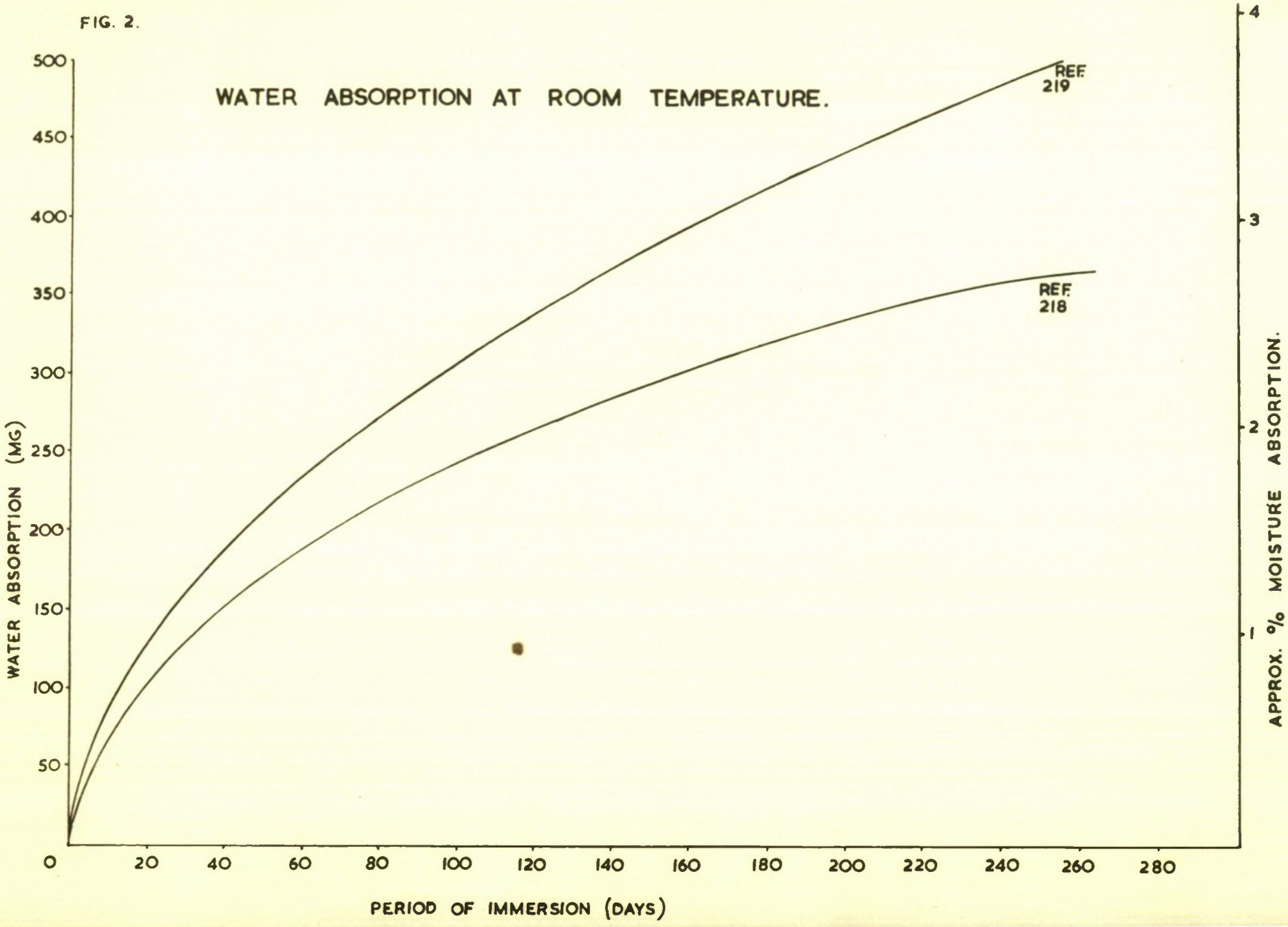


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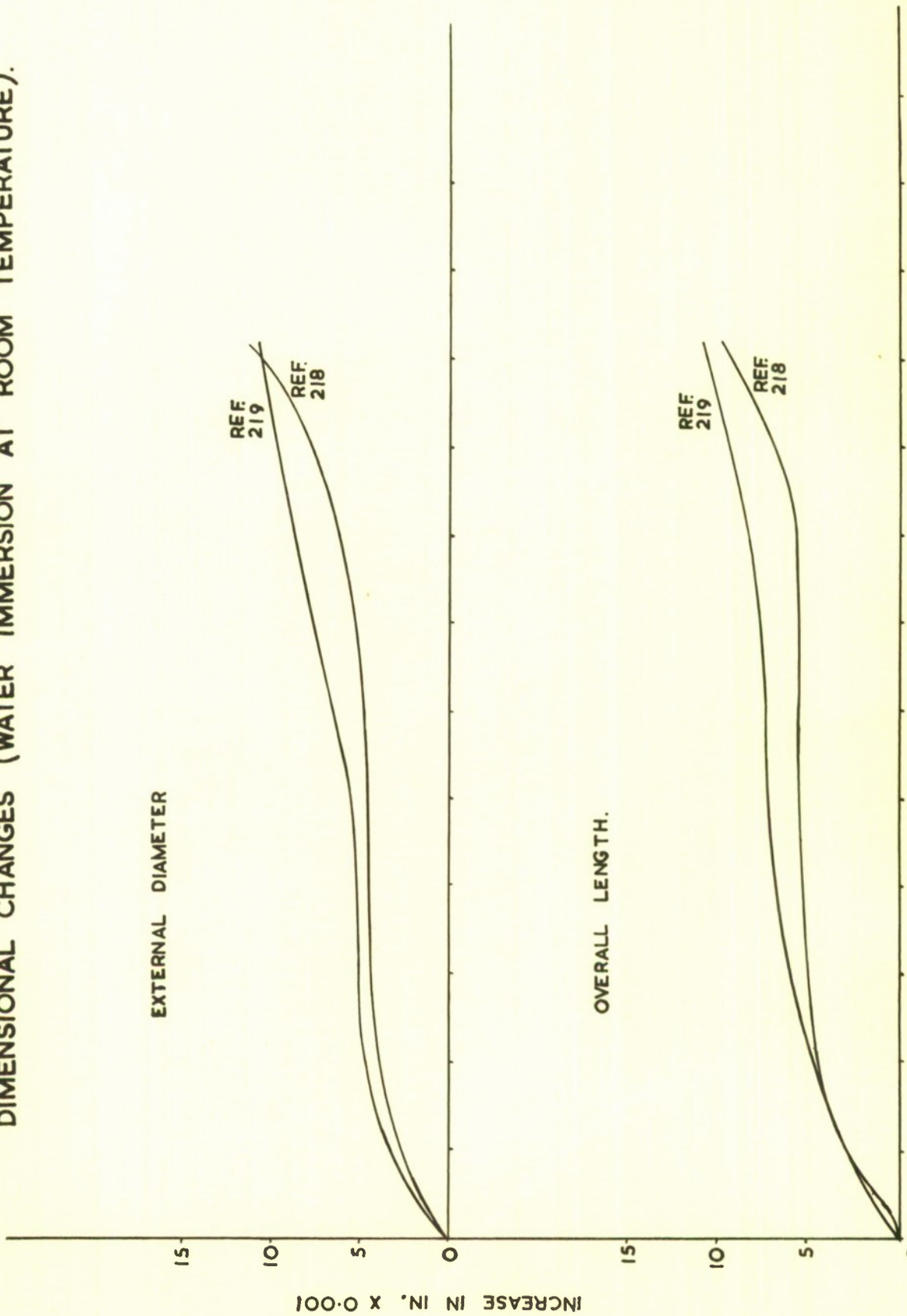
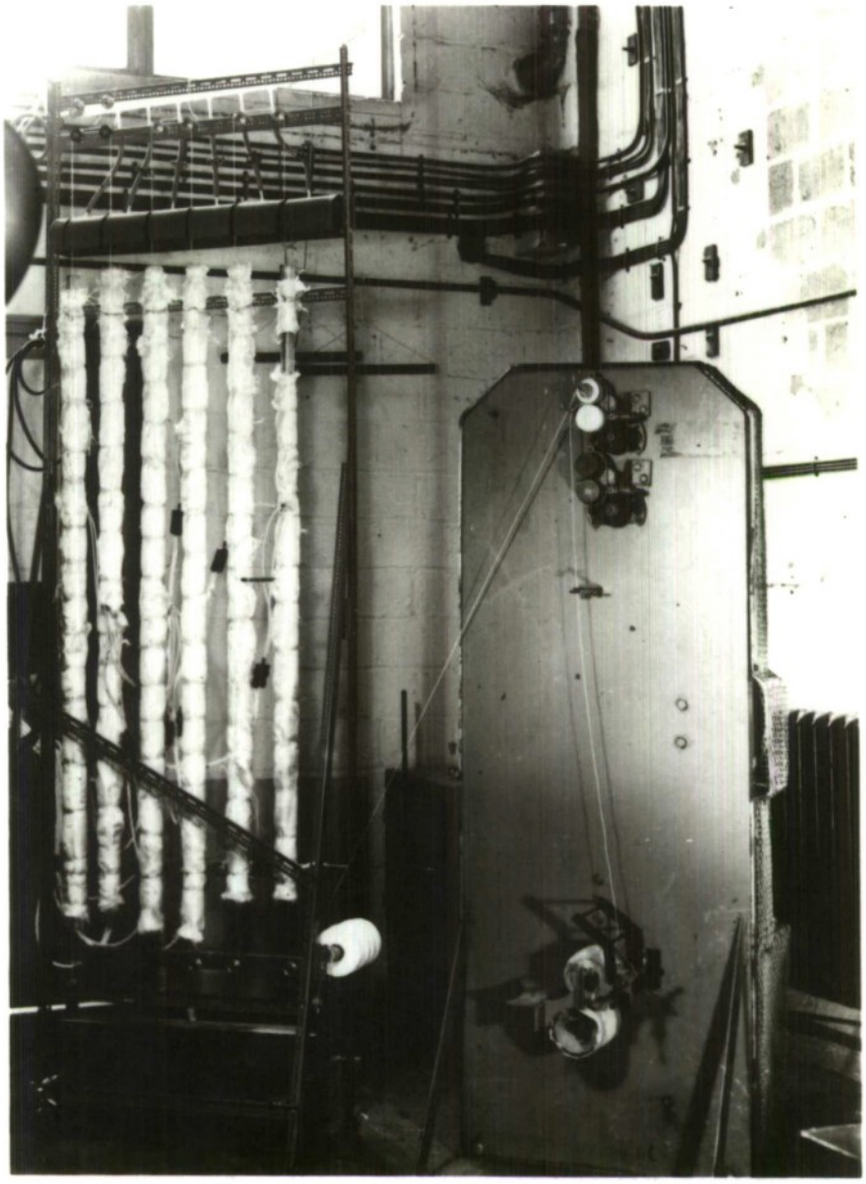
FIG. 3.

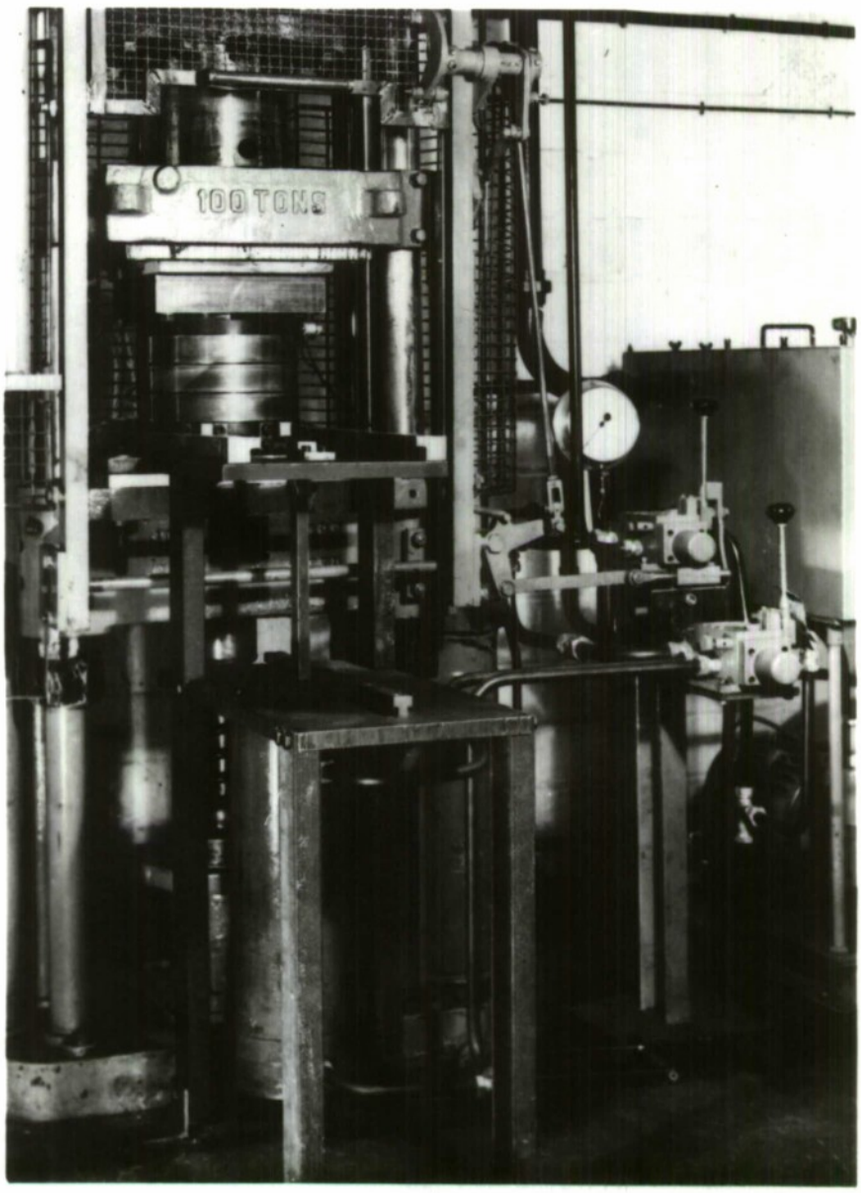
DIMENSIONAL CHANGES (WATER IMMERSION AT ROOM TEMPERATURE).





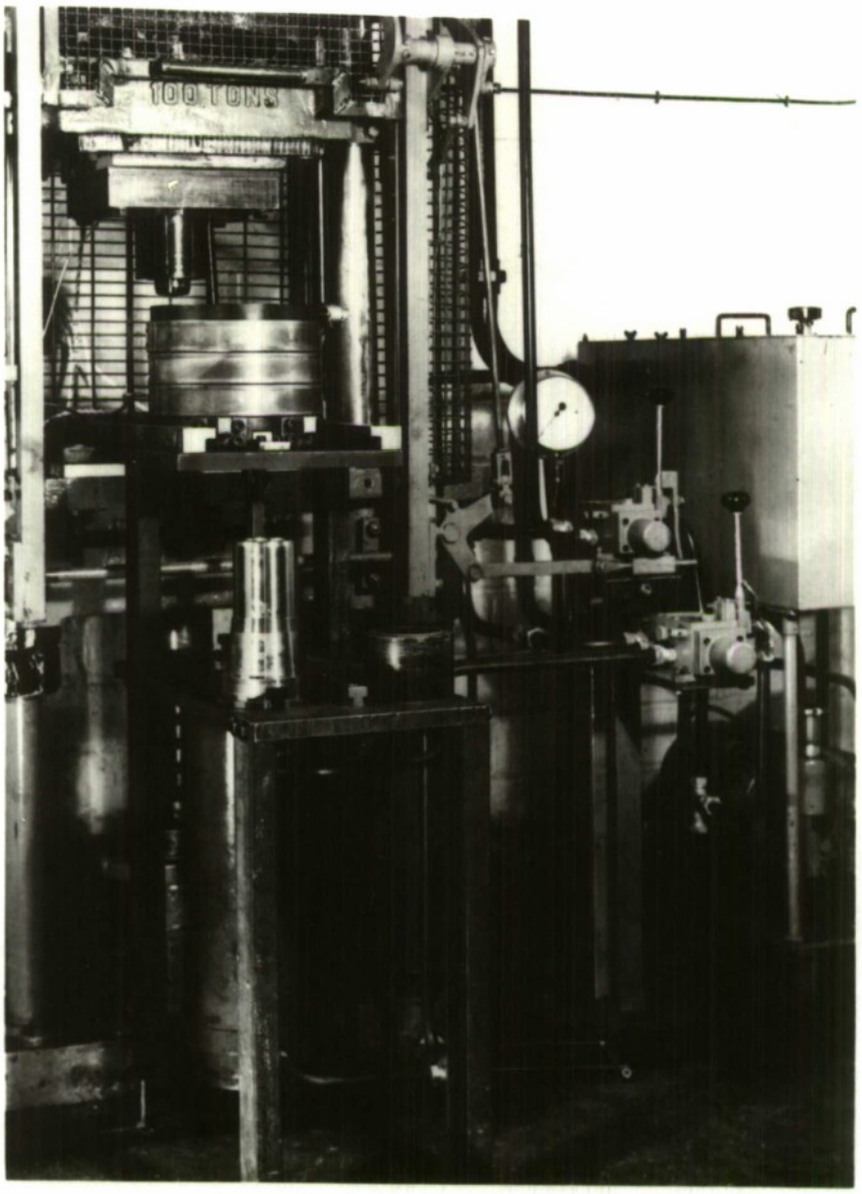
SEMI - SCALE PLANT : COATING EQUIPMENT.

FIG. 4.



SEMI-SCALE PLANT : MOULD ASSEMBLED IN PRESS.

FIG. 5.



SEMI - SCALE PLANT : TOOL (UNASSEMBLED) AND COMPLETED MOULDING. FIG. 6.

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AD#:
Date of Search: 16 February 2007

Record Summary:

Title: Use of non-metallic materials for projectile driving bands: Pt 1, development of a shock-resistant phenolic material
Covering dates 1960
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) DMXRD REPORTS PL/59/4
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